Online May 16, 2024
Journal of Neuroendovascular Therapy 2024; 18: 164–169
DOI: 10.5797/jnet.oa.2024-0003

Original Article

Effectiveness of S-Shaping of the Tip of the FUBUKI Guiding Catheter to Match the Shape of the Cervical Internal Carotid Artery in Anterior Circulation Cerebral Aneurysm Embolization

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Objective: During cerebral aneurysm embolization of the anterior circulation, the guiding catheter (GC) should be placed as distally as possible in the cervical internal carotid artery (ICA) to secure the maneuverability of the microcatheter and distal access catheter. However, if the shape of the tip of the GC does not appropriately match the course of the ICA, blood stasis might occur. We investigated whether shaping the tip of the GC into an S-shape would allow more stable catheterization to the distal ICA than the conventional GC with an angled tip.

Methods: We included patients with cerebral aneurysms of the anterior circulation who were treated at our institution from April 2019 to April 2021. First, we evaluated the cervical ICA course in these patients through cerebral angiography and classified the courses into type S, type I, and type Z. Then, we focused on the most frequently encountered type-S cervical ICA to investigate the forging effect of the GC tip into an S-shape. We evaluated the lateral view of the carotid angiograms to examine whether the catheter tip reached the foramen magnum (FM) without interrupting ICA blood flow. The effects of age, sex, side, a history of hypertension and smoking, and an S-shape modification of the GC tip on the outcome of GC placement were analyzed.

Results: A total of 67 patients were included in this study. The tip of the GC was placed at the FM in 27 cases. Among these factors, only the S-shape modification was significantly associated with whether the GC could be placed at the level of the FM ($p < 0.0001$).

Conclusion: By forging the tip of the GC into an S-shape, the GC can be safely advanced to the distal part of the cervical ICA, which may contribute to the improved maneuverability of microcatheters.

Keywords aneurysm embolization, cervical internal carotid artery, guiding catheter, S-shaping

Introduction

During the embolization of aneurysms, the maneuverability and stability of the microcatheter are instrumental in the success of the procedure. To overcome poor maneuverability due to arteriosclerosis and vessel tortuosity, an intermediate/distal access catheter (DAC) is often used as the support catheter.[1,2] To use these microcatheters and DACs efficiently, the guiding catheter (GC), the basic device of treatment, should be introduced as distally as possible to the cervical internal carotid artery (ICA). However, the distal placement of a GC may stagnate the blood flow of the ICA if it does not match the shape of the cervical ICA. Catheter tip shaping is frequently utilized to adjust the

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Received: January 15, 2024; Accepted: April 12, 2024
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microcatheter to fit into the shape of the target vessel[3–6]; however, to date, no studies have discussed the effects of shaping the tips of GCs. The cervical ICA usually runs in the anterolateral to the postero-medial direction in the bifurcation of the common carotid artery.[7] We hypothesized that forging the tip of the GC into an S-shape could safely guide the GC more distally in the cervical ICA. This way, we evaluated the level of the GC tip during the coil embolization of anterior circulation cerebral aneurysms and compared the results between the conventional and S-shape GCs.

Materials and Methods

Patients and factors investigated

This single-center retrospective study of the GCs was approved by our Ethics Committee of Saitama Medical Center, Saitama Medical University (2021-137). The opt-out method was made available to study participants. The angiographical data of patients who underwent embolization for cerebral aneurysms in the anterior circulation performed at our institution from April 2019 to April 2021 were reviewed. We classified the course of cervical ICA into three types, namely, the sigmoid (type S, **Fig. 1A**), straight (type I, **Fig. 1B**), and tortuous (type Z, **Fig. 1C**) types. The ICA course was classified as I-shaped if there was a straight line from the carotid bifurcation to the carotid canal, S-shaped if there was even a slight curve, and Z-shaped if there was a bend of more than 90°. In the case of embolization of aneurysms in the anterior circulation, we attempted to place the GC into the cervical ICA as distally and safely as possible. From April 2019 to April 2021, 83 endovascular procedures were performed in our department for aneurysms in the anterior circulation, yielding 138 internal carotid angiograms. Among them, 89.1% (123/138) were type S, 0.72% (1/138) were type I, and 10.1% (14/138) were type Z for the course of the cervical ICA. Therefore, we focused on the most frequently encountered type S cervical ICA and investigated the effect of forging the GC tip into an S-shape.

Our routine policy when guiding the GC is to place it as distally as possible during embolization, aiming to place the catheter at the foramen magnum (FM) level. When the GC cannot be advanced to the FM level, we place the catheter at the C2 level. We usually use the ASAHI FUBUKI 7 French 90-cm Angled Stiff type (ASAHI INTECC, Aichi, Japan) GC (the FUBUKI GC) via the transfemoral approach. We excluded cases in which GCs other than the FUBUKI GC were used and those in which a non-transfemoral approach was chosen in the procedure from our analysis. A flow chart of the case selection process is shown in **Fig. 2**. The factors we evaluated were age, sex, left/right, hypertension, smoking, and the shape of the GC's tip. We investigated whether the GC reached the level of the FM or ≤C2 level using the lateral view of angiography (**Fig. 1D**).

Set up of the GC and aneurysm embolization

Originally, we had used the FUBUKI GC in the angled shape without shaping the tip until March 2020 (**Fig. 3A**). In April 2020, we started to forge the tip into an S-shape (**Fig. 3B**) for cases with type S ICA (**Supplementary Video**). Under general anesthesia, the 7 French long sheath was inserted into the right femoral artery, and the FUBUKI GC was guided into the common carotid artery. Intraoperatively, systemic heparinization was performed (the active clotting time was maintained above 275 seconds). A roadmap of the cervical ICA was created by injecting the contrast medium, and the FUBUKI GC was advanced to the cervical ICA at the level of the FM. When the contrast medium stagnated due to spasm or vessel displacement or when the tip of the FUBUKI GC inappropriately made contact with the vessel wall, the FUBUKI GC was gradually pulled back to a lower position.

Statistical analysis

All analyses were performed using JMP Pro 16 software (SAS Institute, Cary, NC, USA). The Student's *t*-test was used to make comparisons between normally distributed continuous variables. The Shapiro–Wilk test was conducted to check whether continuous variables follow a normal distribution. Pearson's chi-squared test was used to make comparisons between categorical variables. Fisher's exact test was used as an alternative to Pearson's chi-squared test because one or more of the cell counts were less than 5. All tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Results

Among the 83 cases of aneurysm embolization in the anterior circulation performed at our hospital, 67 eligible ones were included in this study. **Table 1** shows the clinical characteristics of our study participants. The mean age was 68.1 years (standard deviation: 13.2), and 17 patients (25.3%) were men. The ICA examined was on the right side in 24 cases and on the left side in 43 cases. A history

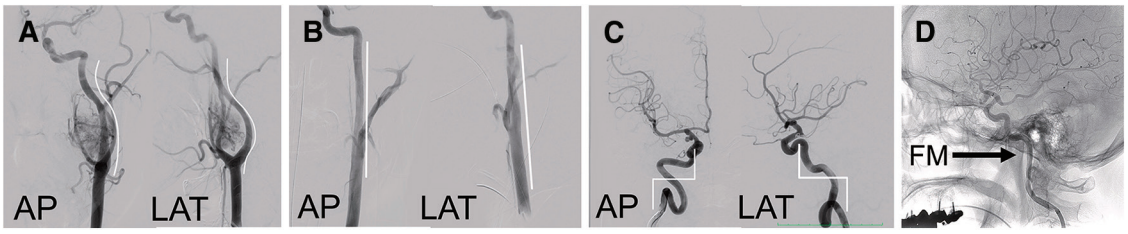

Fig. 1 The cervical internal carotid artery course. (**A**) Type S: AP and LAT views. (**B**) Type I: AP and LAT views. (**C**) Type Z: AP and LAT views. (**D**) The position of the FUBUKI guiding catheter's tip was evaluated using a LAT view of the carotid angiogram. The FM is shown in a black arrow. AP: anteroposterior; FM: foramen magnum; LAT: lateral

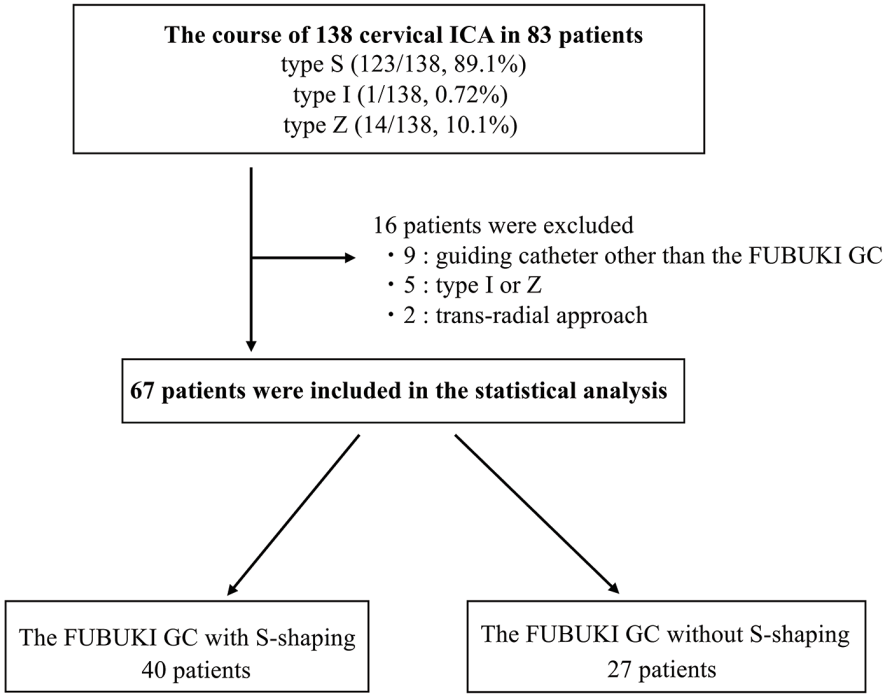

Fig. 2 A flow chart of the case selection process. ICA: internal carotid artery; GC: guiding catheter

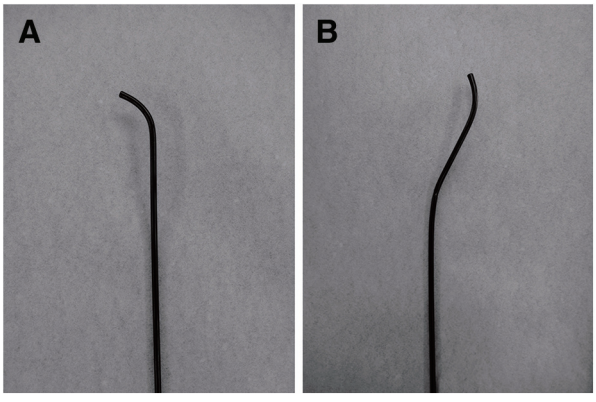

Fig. 3 Tip shape of the FUBUKI guiding catheter (**A**) without shaping (**B**) and after forging the tip into an S-shape.

Table 1 Clinical characteristics of our study participants

Characteristics	N = 67
Age (years), mean (SD)	68.1 (13.2)
Male sex, n (%)	17 (25.3)
Right side, n (%)	24 (35.8)
Hypertension, n (%)	37 (55.2)
Smoking, n (%)	16 (23.8)
Tip modification	
Angled shape, n (%)	27 (40.3)
S-shape, n (%)	40 (59.7)

SD: standard deviation

of hypertension was noted in 37 patients (55.2%). As for smoking, 16 patients (23.8%) were current smokers. The FUBUKI GC was conventional angle-shaped in 27 patients and S-shaped in 40 patients.

We could place the FUBUKI GC to the height of the FM in 27 patients (40.3%). Univariate analyses revealed that only the S-shape was significantly associated with whether or not the FUBUKI GC could be advanced to the FM ($p < 0.0001$) (**Table 2**).

Table 2 Summary of the location of the tip of guiding catheter in 67 patients with anterior circulation aneurysm

	All patients (N = 67)	Univariable analysis		p-Value
		Angled shape (N = 27)	S-shape (N = 40)	
Age (years), mean (SD)	68.1 (13.2)	71.6 (13.4)	65.8 (12.6)	0.08
Male sex, n (%)	17 (25.3)	6 (22.2)	11 (27.5)	0.62
Right side, n (%)	24 (35.8)	9 (33.3)	15 (37.5)	0.73
Hypertension, n (%)	37 (55.2)	14 (51.9)	23 (57.5)	0.65
Smoking, n (%)	16 (23.8)	6 (22.2)	10 (25.0)	0.79
Highest level reached				
C2 or below, n (%)	40 (59.3)	25 (92.6)	15 (37.5)	<0.0001
Foramen magnum, n (%)	27 (40.3)	2 (7.4)	25 (62.5)	

SD: standard deviation

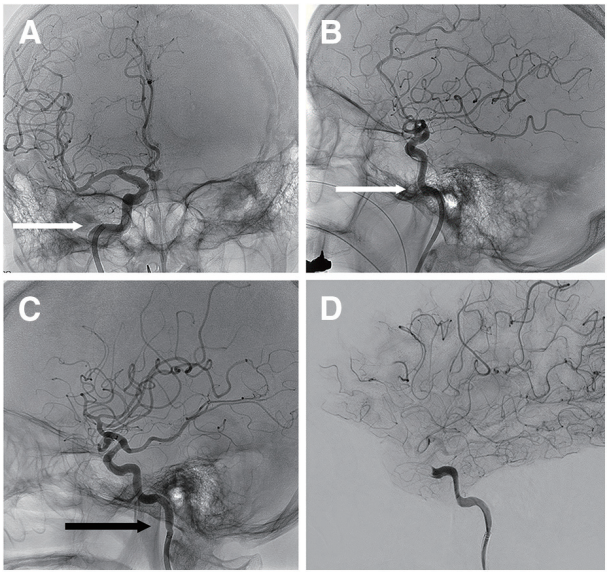

Fig. 4 Illustrative case 1. Right internal carotid angiogram: (**A**) anteroposterior view (**B**) lateral view. The S-shaped tip of the FUBUKI guiding catheter reached beyond the height of the FM to the canalis caroticus (white arrows). No interruption of blood flow in the internal carotid artery was observed. Illustrative case 2. Left internal carotid angiogram lateral view. (**C**) The FUBUKI guiding catheter was guided to the height of the FM without S-shaping of the tip (black arrow). (**D**) Although there was no spasm in the left internal carotid artery, blood flow was interrupted. FM: foramen magnum

Illustrative cases

Case 1

A 70-year-old woman with sudden-onset severe headache and loss of consciousness was transferred to our hospital. Computed tomography (CT) revealed subarachnoid hemorrhage and CT angiography showed a ruptured anterior communicating artery aneurysm with a maximum diameter of 7 mm. Under general anesthesia, the FUBUKI GC was guided from the right common femoral artery to the right cervical ICA. The cervical ICA was S-shaped, so the tip of the FUBUKI GC was forged into an S-shape accordingly. The FUBUKI GC could be advanced beyond the level of the FM (**Fig. 4A**) with no interruption or stagnation of the blood flowing through the cervical ICA (**Fig. 4B**). Tight packing of the aneurysm with coils was successfully conducted under the good maneuverability of the microcatheter.

Case 2

A 75-year-old woman underwent endovascular coiling for an unruptured middle cerebral artery aneurysm. Under general anesthesia, the FUBUKI GC without the tip modification was guided from the right femoral artery to the left cervical ICA. The cervical ICA was S-shaped. When the FUBUKI GC was moved to the level of the FM and ICA angiography was performed (**Fig. 4C**), stasis in the ICA was confirmed (**Fig. 4D**). The blood flow was thought to be blocked because the tip of the FUBUKI GC did not fit the course of the cervical ICA. We had to pull back the FUBUKI GC to the height of the lower end of C2, sacrificing the maneuverability of the microcatheter.

Discussion

Advancing the GC as far distally as possible has the effect of making subsequent manipulation easier.[8] If the shape of the tip of the GC does not match the shape of the cervical ICA, stasis and dissecting injury may occur. The course of the cervical ICA itself greatly influences the catheterization of GC to the distal portion of the cervical ICA.[7] Among these, Type I cervical ICAs are extremely rare (according to our data), and GC catheterization is considered to be quite simple. Meanwhile, Z-shaped cervical ICAs are also relatively rare (10.1%), and they

are frequently not amenable to ordinary catheterization. In this study, we focused on S-shape ICAs because they were the most frequently encountered type. Although treatment-related complications were not analyzed in this study because they are not simply attributable to the difficulty of catheterization, our results indicated that, as with microcatheters, a seemingly small modification at the tip of the GC may improve treatment safety and device usability. The S-shape of the cervical ICA varied from case to case; however, the GC tip was shaped uniformly in this study. Our results indicate that even simple shaping is versatile. We believe that this is particularly useful in therapeutic angiography rather than diagnostic angiography because the stabilization of the intracranial microcatheter and DAC manipulation are critical to the obtention of successful treatment outcomes. The advantage of guiding the GC to a higher position within safe limits is that the microcatheter or balloon catheter and the DAC are easier to manipulate or can be treated without a DAC. DAC is a useful device developed in recent years and is used in many cerebral aneurysm embolization procedures. However, currently available DACs cannot perform double microcatheter-balloon assist techniques or single catheter-double balloon techniques. Therefore, in cases where these techniques are required, the GC should be guided to a higher position within safe limits.

Nevertheless, this study has several limitations. First, the extent to which the GC can be advanced depends on the surgeon's subjective judgment regarding safety, and there may have been inter-operator bias. However, we believe there is sufficient objectivity because, in this study, two or more endovascular surgeons determined how far the GC can be advanced. Second, in this study, we did not investigate whether modifying the shape of the GC tip directly contributes to improved treatment results. Third, the cervical ICA classification depends on the judgment of the endovascular surgeon, which may have influenced the selection of type-S cases in this study. Furthermore, the ICA shape is judged in two directions: anteroposterior and lateral views; however, it is difficult to judge strictly because the depiction of cervical ICA can change depending on the angle of the patient's neck. Fourth, there was no detailed analysis of the causes of difficulties in guiding the GC to higher cervical ICA positions. In addition to type III aortic arch, the degree of meander of the subclavian artery and severity of spasm of the cervical ICA, the extent to which the endovascular surgeon tried to guide the GC to the FM, may influence the outcome. It should be noted that the modification of the GC tip to an S-shape in the statistical analysis caused a significant difference in the results; however, not a few biases exist.

Considering the abovementioned limitations, further studies are necessary to determine whether this method reduces the duration of the procedure and the rate of its associated complications, improves the rate of cerebral aneurysm embolization, improves postoperative imaging findings, or reduces symptomatic embolisms and cervical ICA vasospasm.

Conclusion

Forging the tip of the GC into an S-shape enables it to be advanced to a sufficiently high point of the cervical ICA, which may contribute to the maneuverability of the microcatheter and DAC in cases with S-shaped ICAs, the most common shape of cervical ICAs.

Disclosure Statement

The authors declare that they have no conflicts of interest.

Supplementary Information

Supplementary video

This video demonstrates how to forge the tip of the FUBUKI guiding catheter into an S-shape.

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